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PATENT SPECIFICATION.

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COMPLETE SPECIFICATION.

Improved Method of and Apparatus for Removing Dust or other Foreign Particles from Gas or Air.

We, WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY, of 40, Wall Street, New York, State of New York, United States of America, a corporation organised and existing under the Laws of the State of Delaware, in said United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to electrical gas-cleaning precipitators or similar apparatus for removing dust or dust-particles from gaseous streams, by dust or dust-particles meaning any foreign particulate matter capable of being removed from a gas by electrical means and methods. The invention is useful for the removal of atmospheric-dust from flowing air, but also has an especial usefulness for cleaning process-dust from industrial or other dust-laden gases including gases having high dust-concentrations.

Heretofore electrical precipitators of practical application have operated generally on the principle of electrically charging the dust-particles and then causing the charged dust-particles to migrate to, or deposit on, or be collected by, a plurality of finite oppositely charged precipitating-electrodes of some extent in the direction of gas-flow. The ordinary Cottrell precipitator, used primarily for the removal of fly-ash from flue gases and also for the removal of process dust, is one form of such prior devices in which the dust-particles are charged and collected in a single zone; and the dust-particles are first charged by an ionizing means in one zone and then precipitated or collected by a precipitating means in a subsequent separate zone.

Precipitators utilizing precipitating means comprising extended finite precipitating-electrodes generally permit the precipitating dust to collect or accumulate on the precipitating-electrodes, and as the layer of accumulated dust or dirt on the precipitating-electrodes becomes heavier, the operating efficiency of the precipitating means decreases so that the precipitating-electrodes must be cleaned in some manner if satisfactory gas-cleaning is to be continuously obtained. Many expedients have been devised for removing the accumulated dirt from precipitating-electrodes, which depend upon the particular type and construction of the precipitator, and may include rapping of the precipitating-electrodes to jar accumulated dirt therefrom, usually into a receptacle therebelow; or an occasional washing of the precipitating-electrodes; or arranging the precipitating-electrodes in the form of a vertically disposed movable endless chain or curtain which has a lower portion dipping into a body of oil for soaking the accumulated dirt from the particular portion of the precipitating-electrodes which happen to be immersed in the oil, small portions of the precipitating-electrodes being successively immersed. Other expedients are also known, but, in general, they all permit a layer of dirt to accumulate to some extent on the precipitating-electrodes before they are cleaned.

In certain forms of the present invention, precipitating-electrodes of relatively fixed finite dimensions, to which the charged dust-particles migrate and collect are altogether eliminated, or at least the number or extent thereof limited.

It has, however, been proposed to purify air or gas from dust-particles by passing the air or gas successively through a high tension grid electrode supported by a casing or conduit and a spray of water discharged from a nozzle at a high electric potential, so that if the two potentials are of the same polarity the particles are all attracted by deposit surfaces or if they are of opposite polarity the dust and liquid particles attract one another and are deposited by gravity action. In the case of the present invention, however, the conduit and liquid supply pipe are not at high potentials and can be earthed or grounded.

The main object of the invention is to provide an improved gas cleaning method and apparatus therefor, such as

an electrical dust-precipitator, which has dust-collecting or precipitating means which permits the collected dust to be automatically taken out of the path of the gases substantially as soon as it is collected or precipitated, so that no accumulated dust deposits form in the dust-precipitator.

The invention consists primarily in the method of removing dust-particles from a flowing gas or air, characterised by electrically charging the dust-particles by passing the gas stream through an ionizing electrostatic field of predetermined polarity established between spaced positive and negative electrodes, and then through a spray of liquid passed through another electrostatic field of opposite polarity separately established by a charged electrode which charges the spray by induction with a polarity opposite from that of the dust-particles, whereby the liquid drops and charged dust-particles are caused to attract each other.

The invention also comprises apparatus for removing dust-particles from a flowing gas or air, comprising a gas-conduit having an ionizing zone therein for ionizing the said dust-particles in the gas-stream, a dust-removing means arranged to act upon the gas-stream coming from the ionizing zone, said dust-removing means comprising at least one liquid-spray device and separate field-establishing electrode-means co-operating with the spray-device for electrically charging the liquid-drops of the spray.

In the operation of the preferred embodiments of the invention, the dust-particles in the dust-laden gas are separated from the gas by charging or ionizing the dust-particles therein, and subjecting the charged dust-particles to the action of a curtain or spray of a liquid, which curtain or spray (hereinafter called spray) has been electrically charged or ionized in such a manner as to cause the charged dust-particles to be attracted to the charged spray-drops. The spray is established in the path of the gas-flow, so that the gas containing the charged dust-particles must pass through the oppositely charged droplets of the spray, and this results in a thorough mixing and intermingling of the charged dust-particles and the oppositely charged liquid-drops of the spray. By subsequently separating the gas and the spray-liquid, it is possible, as proved by cleaning-efficiency tests, to remove a large portion of the dust-particles from the gas-stream, said dust-particles having been transferred to the spray-liquid, the proportion of dust-removal being an indication of the gas-cleaning efficiency.

Although other theories or explanations may be possible, the dust-removal, meaning foreign-particle-removal, from air or other gas, is effected, in accordance with the following principles and processes: Charged dust-particles and oppositely charged spray-drops have a tendency to attract each other, although there may also be actual contact due to their movements in the spray-region. When a charged dust-particle contacts an oppositely charged spray-drop, the two thereafter apparently move together, the dust-particle apparently flowing with the spray-drop, so that the gas is cleaned, and the dust-particle can, therefore, be considered as being attached or adhering to a spray-drop, so that it can be separated from the gas-stream with the spray-liquid.

For the spray-producing means, a liquid or solution is preferably utilized which is easily obtainable and which will not readily catch fire. A number of liquids are suitable, but for the embodiments of the invention shown herein, it is believed that the spraying liquid should preferably be conductive, at least to some slight extent, so that the stream of liquid, as it leaves the spraying nozzle, will conduct the charging-current up to the point, a short distance from the nozzle, where the liquid-stream breaks up into discrete spray-particles or spray drops. Ordinary tap-water, and even ordinary distilled water, has a sufficient amount of conductivity; and at any rate it is very satisfactory. Tap-water has the additional advantage that it need not be collected after it has cleaned the gas unless it is desired to use the water for some other purpose, or to recover the collected dirt which might, in some instances, especially in the removal of process-dust, be valuable.

The use of water as the spray-material has the added advantage that the gas-cleaning equipment herein described may be combined with air-conditioning equipment if the gas to be cleaned is air, since the water-spray is also useful for washing the gas, and, for controlling its humidity or conditioning it.

It has been found that, in general, the smaller the charged liquid-drops, the better the dust-collection, provided that a sufficient quantity of liquid is sprayed across the gas-stream, and provided that the sprayed liquid is subsequently completely removed from the gas-stream. However, while small drops are preferable from the standpoint of ease of attachment to dust-particles, the water-

droplets must not be so small that they cannot be acted upon by forces, such as, for example, electrical forces or gravitational forces, which can be utilized to separate the dust-laden liquid from the cleaned gas-stream, so that the quantity of cleaning liquid carried along with the cleaned gas-stream can be kept to as low an amount as possible or desired. In general, the liquid-spray is continuously supplied, so that the dust-precipitation is continuous, and the dust-laden liquid is continuously removed from the gas-stream, so that the removal of the precipitated dust is also continuous.

In the preferred embodiments of the invention, a two-stage or two-zone gas-cleaner is utilized, that is, the dust-particles in the gas-stream are first charged by passing the dust-laden gas through an ionizing electrostatic field which contains only the flowing gas and the ionizing means, and then passing the gas, now laden with charged dust-particles, through an electrified or charged liquid-spray which follows the ionizing field in the direction of gas-flow, the electrified liquid-spray constituting a part, or all, of the means for precipitating the dust.

The ionizing electrostatic field may be obtained by an ionizing means constructed and operated in any convenient way, and may take the form of an ionizing electrode substantially axially located in, and insulated from, a cooperating non-discharging tubular electrode through which the gas to be cleaned passes. Or the ionizing means may comprise one or more spaced ionizing electrodes spaced between, and insulated from, larger non-discharging electrodes substantially transverse to the gas-stream. Of course any suitable structural arrangement can be utilized with the invention so long as it will provide an adequate electrostatic field for charging the dust-particles in the dust-laden gas.

The region in which the charged dust-particles are removed from the gas-stream includes the precipitating means which, in the preferred modifications of the invention, includes one or more spray-means, such as, for example, spray-nozzle or spray-pipes, located near oppositely charged field-establishing electrode-means for causing the liquid drops coming from the spray-means to be ionized or charged with a charge of a polarity which is opposite to that imparted to the dust-particles in the dust-charging ionizing electrostatic field. The spray-nozzles may each have a small tubular liquid-discharge tip so that a highly concentrated electrostatic field can be produced at the liquid-discharge tip by the field-establishing electrode-means associated therewith, which is preferably in the form of a loop or loops located at a suitable distance from the discharge-tip of the nozzle.

It has been found that a charged liquid-spray for the precipitating-means of the novel gas-cleaning precipitator may establish a space-charge in the spray-region in the gas-conduit. Such a space-charge may be sufficiently intense to cause numerous flashovers and break-downs which have the disadvantage of slightly increasing the power-consumption of the device, and of tending to produce undesirable ozone or nitrous oxide, where the gas being cleaned is air, and of temporarily adversely affecting the electrostatic fields of the gas-cleaning precipitator and thereby lowering the cleaning-efficiency. Additionally, the space-charge may limit the amount of spray-liquid which can be utilized in its spray-region, and in such cases it is desirable to use two or more sprays in series, each spray being preferably, but not necessarily, preceded by a dust-charging zone.

By incorporating suitable field-affecting means in the spray, the space-charge can be limited or neutralized, and by utilizing extended suitably charged or grounded electrodes, such as flat, curved or bent plates, for such neutralizing means, the charged liquid-drops can be caused to collect partially, or totally, on the plates which, therefore, also serve as a separator or separating-means for separating spray-liquid from the cleaned gas-stream.

The invention will become apparent from the following description of several embodiments thereof, shown by way of example in the accompanying drawings.

Figure 1 is a vertical sectional view of an embodiment of the invention disposed in a horizontal gas-conduit;

Figs. 2 and 3 are horizontal sectional views illustrating modifications of the invention shown in Fig. 1;

Fig. 4 is a vertical sectional view illustrating modified forms of ionizing means and precipitating means for a precipitator embodying the teachings of the invention;

Fig. 5 is a view similar to Fig. 4, illustrating a gas-cleaning precipitator having two combined cooperating gas-cleaning means in a single gas-conduit;

Fig. 6 is a vertical sectional view of a gas-conduit including another form of the invention in which the gas flows vertically downward; and

Fig. 7 is a view similar to Fig. 6, illus-

trating a modified form thereof.

In general, the structural features of the invention shown herein comprises a gas-conduit means for guiding the flow of the gas to be cleaned, and disposed in the gas-conduit means, successively in the direction of the gas-flow, are: a dust-charging means comprising an ionizing zone having an ionizing means for establishing an ionizing electrostatic field through which the gas flows and in which the dust-particles in the gas are charged; a dust-precipitating means comprising an electrified spray-means for establishing a charged liquid-spray spreading across the conduit in such manner that gas flows through the spray; and other means or expedients for separating the liquid-spray drops from the cleaned gas. Means for decreasing the space-charge which the charged spray tends to establish in the spray-region may also be included.

In Fig. 1, the gas-cleaning precipitator or apparatus 2 comprises a metallic gas-conduit means having a horizontal conduit-section 4 and a vertical duct 6. The gas-flow is indicated by the arrows 7, and a portion of the upstream side of the conduit-section 4 includes the ionizing zone 8 comprising ionizing means including a transversely and insulatedly supported ionizing wire 10 spaced between two grounded tubular non-discharge electrodes 12. The electrodes 10 and 12, when suitably energized, establish an ionizing electrostatic field in the ionizing zone 8. In this form of embodiment, the conduit-section 4 will usually be rectangular.

The ionizing wire 10 is preferably relatively fine so that utilizable ionization of the dust-particles in the gas may be obtained at wire-charging voltages in the gas-stream, producing charging currents, yielding negligible ozone-generation and requiring a small power-input when the precipitator is used commercially in air-cleaning systems. The grounded tubular electrodes 12 are usually hollow rounded metallic rods of suitable size which is relatively large compared to that of the relatively fine ionizing wire 10. Preferably positive ionization is utilized in the embodiment shown in Fig. 1, and to this end the ionizing wire is connected to the positive pole of a suitable source of electrical energy, as indicated at P+, the negative terminal P− of the power source being grounded so that, in effect, the grounded electrodes 12 are electrically connected thereto.

For the energization of the various elements of the invention, a limited energy power-conversion means is preferably used which converts the customary commercially available alternating current power-supply to a unidirectional power-supply useful for precipitating apparatus of this kind, for cleaning air to be breathed, and includes safety provisions permitting the converting-means to withstand repeated short-circuits, and signalling-means for indicating faulty conditions of the precipitator.

The precipitating means of the embodiment of Fig. 1 comprises a spray-nozzle 14 having a discharge-tip 15 disposed at or slightly above the longitudinal center of the conduit-section 4, the spray-nozzle being continuously fed with a supply of liquid, in this case water, from a supply-pipe 16. The spray discharged from the discharge-tip 15 of nozzle 14 is indicated at 18 and is spread out sufficiently to ultimately occupy the full transverse area of the conduit-section 4. Located slightly away from the discharge-tip 15 is a suitable field-establishing electrode means. This field-establishing electrode means may be a loop in the form of a completely circular metallic ring 20, which may be either completely closed or split. The ring 20 is supported by a supporting arm 21 carried by an insulator 22 secured to the conduit-section 4. The ring 20 is excited, or given a predetermined potential, by an insulated conductor 24 passing through the conduit. For electrifying or charging the spray, a unidirectional power-supply has its negative terminal P¹− grounded and its positive terminal P¹+ connected to the conductor 24, so that the circular metal ring 20 is at a positive potential with respect to the conduit-section 4 and therefore at a positive potential with respect to the conduit-tip 15 of the nozzle 14, which is grounded to the conduit by a grounding connection of the water-supply pipe 16, the nozzle and the pipe being preferably metallic. In some cases, the same power-supply may advantageously be utilized to establish a field between the discharge-tip 15 and the ring 20, and to energize the ionizing electrode-means of the ionizing zone 8.

The positively charged ring-electrode 20 establishes an electrostatic field between itself and the negatively charged nozzle 14, the field being highly concentrated at the small discharge-tip 15, so that the spray-drops are charged negatively by contact and induction. The electric forces established at the discharge tip of the nozzle charge the spray-drops, and these forces also tend to spread the drops and even to decrease their size. In general, a pointed nozzle will give a stronger field-gradient at its

tip, and hence a greater spray-charging effect than a hole in a square-fronted surface. In general, also, a field-establishing ring 20 or grid of any kind, will have a stronger field-establishing effect, and hence a greater spray-charging effect. the greater the aggregate transverse cross sectional areas of its component wires; and more particularly, the wire or wires of the field-establishing electrodes should each be of a sufficiently large size to avoid point-electrode effects or high local gradients at the wire-surfaces.

During the gas-cleaning operation of the device shown in Fig. 1, the spray is continuously sprayed into the path of the flowing gases. Inasmuch as the dust-particles in the gas have previously received a positive charge, in passing through the ionizing zone 8 before reaching the spray, and inasmuch as the liquid-drops of the spray 18 are negatively charged, the charged dust-particles will be attracted by, and become mechanically attached to, the oppositely charged droplets of the spray 18. Of course the polarities of the fields may be reversed, so that the dust-particles are charged negatively and the spray-drops positively.

The spray being water in the preferred embodiment, any dust-particles which are soluble may actually be dissolved in the water-spray, but insoluble or slightly soluble charged dust-particles will be attracted to the oppositely charged spray-drops by electrical forces and by passing into contact therewith when the gas flows through the spray 18. When the dust-particles do not have a good tendency to adhere to the spray-drops, a wetting agent may be added to the spraying liquid. In air-cleaning, however, the wetting agent chosen should preferably be non-corrosive, free from harmful effects, and not accompanied by operational hazards. Where water is used for the spray, the wetting agent which is added thereto may also serve to lower the freezing point of the spray liquid. Sodium or potassium carbonate, and ethylene glycol are satisfactory in this respect, although other agents can be used. A wetting agent added to the water also causes the spray-drops to be finer, and may improve the cleaning efficiency.

It is preferable to utilise a spray in which the drops are larger than fog-mists, but finer than drops that drip by gravitational action from a downwardly direct sharp point of a well wetted object. In general, such drops are finer than rain-drops or drops coming from a pipette of 1 mm. inner diameter and 2 mm. outer diameter. However, the drops should not be so fine that they cannot be separated from the flowing gases, and it is believed that, for best results, drops of about 100 to 500 microns in size are preferred, although they may be as large as 1000 microns and above, and possibly as small as 10 microns. Sometimes it is desirable to use spray-drops having a size on which gravity may exert sufficient pull, against the pressure of the air-stream, so that by merely properly vertically diverting the gas-stream, the spray-liquid can be separated from the cleaned gas.

In the embodiment shown in Fig. 1, the liquid-drops are separated from the cleaned gas by a threefold means; partially by gravity; partially by causing the gas-stream including the spray-drops to impinge upon a plurality of spray-agglomerating and water-separating baffles 30, all of which are conductively connected to the gas-conduit, or all of which are even maintained at a predetermined potential such as a positive potential with respect said gas-conduit; and partially by the inertia of the spray-drops causing them to impinge upon the far or back side of the upturned duct-portion 6. Some of the charged spray-drops may also be electrically attracted to the grounded metal sides of the gas-conduit section 4. The separated liquid, resulting from the collection of the spray-drops, flows down the downwardly-sloped bottom 32 of the conduit-section 4, to an out-flow pipe 34 dipping into a seal 36 having a discharge 38 above the bottom of the outflow pipe 34. The seal 36 prevents leakage of the gas through the outlet pipe 34.

Fig. 2 shows an ionizing means and a precipitating means for a gas-conduit of larger cross-sectional area. This embodiment utilizes as many ground electrodes 50 and ionizing wires 52 as the size of the conduit requires, one or two ionizing wires being insulatedly supported from a ground electrode.

The precipitating means, however, comprises one or more elongated water-supply pipes 54 provided with a plurality of discharge-spray nozzles 56 spaced along the length of the supply pipe or pipes 54. Each nozzle has, associated and cooperating therewith, a loop-electrode 58 which, in this embodiment, is a completely circular metallic ring. The adjacent rings 58 may conveniently contact each other so that all of them can be excited by a single high-voltage conductor 24.

However, in large units, and even in

smaller units, the resulting charged liquid-spray may establish a large space-charge in the region of the spray, and this space-charge may have, at times, a potential-gradient above the breakdown-voltage of the gas flowing theretbrough, which would cause frequent flashovers and arcs disturbing the operation and the efficiency of the gas-cleaning precipitator. To keep this potential-gradient within reasonable limits, and specifically below the flashover value, field-affecting means may be provided in the area occupied by the portion of the water-spray on the downstream side of the spray-charging electrodes. This field-affecting means, in the embodiment shown in Fig. 2, comprises a plurality of electrodes in the form of substantially parallel metal plates 62 and 64 between which the water-spray passes. The plates 62 and 64 are maintained at a potential suitable for neutralizing or minimizing the negative space-charge accumulated by the negatively charged spray-particles. In Fig. 2, the plates are illustrated as grounded plates. The upstream sides of these plates are spaced from the rings 58 by a distance which will avoid too high a field-concentration between the grounded plates and the high-voltage rings, and the extent of the plates should be sufficient to perform their intended field-controlling function.

Since, in general, the total charge on the dust-particles is small compared to that on the spray-drops, the space-charge in the portion of the conduit occupied by the metal plates 62 and 64 is determined primarily by the charge on the spray-drops; but under the influence of the space-charge field the spray drops are driven to the grounded plates 62 and 64, thereby weakening the space-charge field. Additionally, the metal plates provide extended areas of ground-potential, distributed across the spray, so that large overall potentials between two points in the spray-region are prevented.

For typical air-washers for air-conditioning systems, as heretofore known, the weight of the water supplied is of the order of 55% of the weight of the air being cleaned. In the present system, if it is assumed that the spray-drops are 10^{-2} cm. in diameter, which is the equivalent of approximately 1270 drops per cu. cm., and if it is assumed 10^6 electrons per spray-drop, which is reasonable for a spray-drop of this size, there will be a space-charge of 1.27×10^9 electrons per cu. cm. This value is in the order of 10,000 times the aggregate charge on all of the dust-particles on a smoggy day, so that the charge on the dust-particles can be neglected in considering the space-charge in the region of the spray immediately following the spray-charging electrodes such as 20 or 58. If it is assumed that the air-stream carries these charged spray-drops between the parallel plates 62 and 64, the space-voltage will be a maximum midway between a pair of adjacent plates and will vary as the square of the plate-spacing, with a maximum voltage-gradient at the surfaces of the plates, which gradient varies directly as the spacing between plates.

In this non-uniform negative field between any two plates 62 and 64 of Fig. 2, the negatively charged water-droplets and the positively charged dust-particles which are at any point other than the exact center of the space between the plates will be subject to electrostatic forces tending to move them toward or away from the plates. The positively charged particles, namely the dust-particles, move toward the center of the space between the plates, where the negative potential is the greatest. The negatively charged particles, which are the spray-particles, move in the opposite direction, or towards the nearest plate. It is desired that those pairs of these oppositely moving and oppositely charged particles which pass close to each other shall have time to be attracted into contact with each other. The attractive force between any pair of oppositely charged particles varies inversely as the distance between their centers, and hence no effective attractive force exists at all, except when the particles are within a few diameters of each other, referring to the diameter of the larger particle, which is usually the water-droplet. It is obvious that if the opposite velocities of the oppositely charged particles are too great, under the influence of the general space-charge field, very few of these pairs of particles will ever get close enough together for their mutual attractive forces to pull them together.

From the standpoint of the chance of any given charged dust-particle coming into contact with an oppositely charged spray-drop, the plates 62 and 64 should be very close, so as to produce a low-voltage gradient in the space between the plates. However, as the plates are brought nearer, this very reduction in the voltage-gradient also reduces the number of spray-drops which are driven past any given dust-particle. For this reason, the plates need only be sufficiently close to prevent sparkover between spray-drops; and under the conditions assumed, this spacing would be in the order of about two to five inches (5—12.7 cm) on the up-

stream side, which spacing may be increased further on the downstream side because of the lessened charge-density due to the loss of water-droplets. Accordingly, alternate plates 62 may be made shorter, as indicated in Fig. 2, in which the downstream edges of the plates 62 terminate before the downstream edges of the plates 64.

The spray-nozzles 15 and 56 hereinabove described are of the type which are designed to eject a somewhat conical spray, but it is possible to obtain the spray in any other convenient manner, and in Fig. 3 the spray is obtained by the use of air-pressure. In this embodiment, the ionizing zone 70 is constructed in any suitable manner, and the precipitating means comprises a water-supply pipe 72 having a discharge-tip 74. A second pipe 76 conveys air under pressure to an air-discharge nozzle 78 which blows across the outlet of the water-discharging tip 74, thereby establishing a water-spray flowing in the direction of the gas-stream. Such a spraying means is useful for the cleaning of process-dust where the degree to which the gas is cleaned is not the sole objective. However, the gas which is supplied to the air-pressure pipe 76 may be tapped from the cleaned-gas side of the system in instances where the cleanliness of the out-flowing gas is an important consideration.

More than one electrode may be used for the high-potential electrode-means of the spray-charging means, and a plurality of field-establishing electrodes may be arranged in the direction of the gas-stream for establishing the field for charging the spray-drops. Thus, in the embodiment shown in Fig. 3, the field-establishing loops comprise a plurality of contacting metal rings 80 and 82 of substantially the same size and aligned in the gas-stream direction.

The grounded field-affecting means of the embodiment shown in Fig. 3, for reducing the space-charge in the spray, comprises a plurality of grounded plates 86 and 88, which are conductively attached to the gas-conduit, and which are bent or corrugated so that they will better trap the spray drops and thereby also act as a separating means for separating the spray from the flowing cleaned gas.

A modified form of the invention is shown in Fig. 4 in which the precipitating means comprises a charged or excited insulated ring 90 for electrifying the spray created by the spraying-means comprising a water-supply pipe 92 and a compressed-air pipe 94. However, in this embodiment, the gas-conduit is preferably in the form of a circular tube. Such a gas-conduit means adapts itself to the use of a co-axial ionizing wire 96, extending longitudinally of the gas-conduit, rather than transversely as in the prior embodiments, with the outer tube 100 of the conduit itself acting as the non-discharging ground-electrode of the ionizing means. The ionizing wire 96 is supported from insulators 98 carried by the gas-conduit 100, which is grounded.

Where the novel air-cleaning system is newly constructed for a new system, the size of the different parts can be determined for maximum efficiency of the system as a whole. However, if the invention is to be applied to existing gas-flow systems, it may be desirable to cascade, or to arrange in series of tandem, a plurality of successive gas-cleaning means, and in Fig. 5 such an embodiment is shown, which follows the embodiment of Fig. 4. In this embodiment, a second or additional ionizing zone and precipitating means, generally similar in all respects to those of Fig. 4, are inserted in the gas-stream so that the gas undergoes two cleaning operations. However, it is desirable to drive the spray-drops leaving the first gas-cleaning means to the conduit-walls before the gas enters the subsequent gas-cleaning means, and to this end a field-producing means comprising an insulatedly supported ionizing wire 110 is provided, which is negatively charged, as indicated by P−, whereas the ionizing wire or wires 96 of the gas-cleaning means 112 on the upstream side, and the ionizing wire or wires 113 of the gas-cleaning means 114 on the down-stream side, are positively charged, and the spray-drops are negatively charged, so that the negatively charged spray-drops from the first gas-cleaning means 112 will be repelled toward the conduit-walls and will be prevented from entering the ionizing zone of the second gas-cleaning means 114.

The embodiments thus far described have been shown as placed in horizontal gas-conduits, but the invention is readily adaptable to vertically flowing gas-streams, and in Fig. 6 such an embodiment is shown, in which the gas-flow is indicated by the arrows 120. In this embodiment, the gas-conduit 122 is a hollow round tube, and includes an ionizing zone 124 and a precipitating zone 126. The ionizing zone comprises a positively charged ionizing wire 127 co-axially arranged in an inner metallic circular tube 128, this inner tube being provided within the conduit 122 in order to obtain a more concentrated ionizing

field. Suitable annular closing-baffles 130 and 132 prevent gas-flow between the inner tube 128 and the outer gas-conduit 122.

The precipitating zone 126 of Fig. 6 includes a precipitating means shown as comprising a spray-nozzle 134 having a discharge-tip 136 substantially axially arranged in the gas-conduit 122. A high-voltage ring-electrode means 138 is arranged concentrically in the tube 122, and is spaced from the discharge-tip 136 of the nozzle 134 so that the spray will be suitably charged. The ring-electrode means 138 comprises two concentric rings 138^{I} and 138^{II}, and two additional rings 138^{III} and 138^{IV} spaced slightly on the down-stream side of the rings 138^{I} and 138^{II}. All four rings are conductively connected together, and charged by the insulated conductor $P^{1}+$. The spray may be separated from the cleaned gas by the provision of a gas-outlet pipe 140 having a down-turned elbow 142 within the gas-conduit 122, so that the cleaned gas is caused to completely reverse its flow, in leaving through the outlet-pipe 140. This causes the spray, because of its momentum and the action of gravitational forces, to be collected in a trap 144 which is provided at the lower end of the conduit 122. Any suitable field-affecting means can be added in the spray-region for limiting the space-charge therein, and also for collecting spray-liquid.

Air has been cleaned containing atmospheric dust, fly ash, and carbon black, in an apparatus similar to the construction shown in Fig. 6, having the following physical arrangements.

A 5-mil (0.127 mm.) tungsten ionizing wire 127, approximately 15 inches long (38 cm), and symmetrically spaced with respect to an inner metal tube 128 having an inner diameter of 3 inches (76 mm.) and a length of 12 inches (30 cm.) was concentrically placed inside a gas-conduit pipe having a diameter of 6—3/8 inches (16 cm.) throughout the ionizing zone and the precipitating zone. The precipitating zone included a spraying-nozzle 134 which had its discharge-tip 136 about 8 inches (15 cm) from the bottom end of the ionizing wire. The high-voltage field-establishing electrode means 138 comprised two pairs of concentric rings 2—7/8 and 3—1/8 inches (53 mm. and 79 mm.) in diameter, respectively, the first pair being on the downstream side of, and about 1 inch (25 mm) from the discharge-tip 136 of the spraying-nozzle, and the second pair being ¼ inch (6 mm) on the downstream side of the first pair of rings. All four rings were of 1/16" (1.5 mm) wire, and conductively connected together.

The use of electrostatic fields, in addition to a water-spray, appears to be important. Thus, various tests have been made with a specific precipitator as shown in Fig. 6, and having the physical arrangements just described.

In one test, both charging-voltages were left off, both from the dust-charging ionizing wire 127 and from the spray-charging ring-electrode means 138, and it was found that the dust-cleaning efficiency of just an uncharged water-spray, for removing atmosphere dust from air, with the dust uncharged, was 13.8%, on the basis of a "blackness" test, which compares the discoloration, as measured by transmitted light, of filter papers on the upstream and downstream sides, respectively, of an electrical dust-precipitator. Then, by charging the water-spray with a unidirectional potential of between 9 and 10 kilovolts, with the spray-nozzle negative, as shown, but still without any dust-charging voltage on the ionizing wire 127, the dust-cleaning efficiency was increased to 21.5%. Or, by charging the ionizing wire 127 positively with a unidirectional potential of about 12.5 kilovolts, and using an uncharged water-spray, a dust-cleaning efficiency of 34.9% was obtained. Finally, when using charged dust and a charged water-spray, an efficiency of 44.8% was obtained.

The precipitator, utilizing a dust-charging ionizing electrostatic field and a charged water-spray, was also successfully used for removing fly ash from air with very high efficiencies, and even satisfactorily removing kerosene lamp-black from air.

The amount of charging-current carried away by the water-drops will depend upon the voltage between the spray-nozzle and the spray-charging high-voltage ring-electrode means. The charging-current, for a fixed spacing between the spray nozzle and ring-electrode means, was improved with increasing voltages, up to an optimum value which was approximately that used in the previously described cleaning-efficiency tests. Voltages above the optimum value seemed to decrease the charging-current to the water-spray, but this might be attributed to the possibility of the ring-electrode means changing from a non-discharging electrode to a discharging electrode, positively charged.

The amount of charge which is applied to the spray is also affected by the spacing between the spray-nozzle and its cooperating electrode-means. The charging-current (and hence the charges on the

water-droplets of the spray) is generally increased with closer spacing between the ring-electrode means and the spray-nozzle, although an optimum value of spacing also appears to exist. However, with relatively wide spacings, the charging-current rapidly decreased with still further increased spacing between the ring-electrode means and the nozzle.

The amount of charging-current delivered to the water-spray is also affected by, and almost in direct proportion to, the rate at which the water is supplied to the spray-means, the charging-current being larger with increased spray-flow, bearing in mind that a spray-nozzle may have a limiting spraying capacity. The practical limit to the amount of water which may be put into any single spray will depend upon the practical limits of the closeness of the spacing of the field-neutralizing electrodes, such as, for example, the plates 30 (Fig. 1). In certain cases, the total amount of water which is used may be divided into two or more sprays, as shown in Fig. 7.

The electric-cleaning effect of the spray can be conveniently adapted to air-conditioning, for sprays of cold water are frequently used for summer air-conditioning, and warmer sprays are frequently used for humidifying air in winter, so that the spray can, in such cases, serve to cool or warm the cleaned air. Additionally, the spray itself may be used to dissolve or react with contaminating substances in the air, such as obnoxious odors or dissolvable dust-particles. If smoky air which contains SO_2 is to be cleaned, the addition of some alkali to the water to neutralize the acidic conditions formed by the removal of the SO_2 is desirable.

A recirculating system for the cleaning water can be provided, if desired, the water being pumped in any conventional manner with suitable filters provided to remove the dust entrapped in the water. Such recirculating systems would be desirable for cleaning gases or air with liquids which must be treated or are too expensive to permit the use of a fresh supply at all times.

The system of Fig. 6 also shows means whereby the cleaning-liquid may be recirculated by means of a pump 145 having an inlet pipe 146 including a dirt-filter 148, the inlet pipe dipping into the tray 144. The pump 145 pumps the liquid through a discharge-pipe 150 to the nozzle 134, and a system of this kind is useful where the cleaning-liquid is treated. For example, if the dust being collected is very dry, it may be desirable to add a wetting agent to the water, or if the cleaning system be part of an air-conditioning system, it may be desirable to utilize a water solution including a hygroscopic substance, such as $CaCl_2$ or similar agents, for controlling the humidity of the outflowing gas.

Better efficiencies of cleaning can usually be obtained, especially in the smaller sizes of gas-conduits, such as shown in Fig. 6, if a plurality of gas-cleaning means are arranged in series, as shown in Fig. 5. Fig. 7 shows a modification of the Fig. 6 construction whereby better dust-cleaning efficiencies may be obtained by utilizing a plurality of spray-nozzles arranged in the gas-conduit along the direction of gas-flow. This embodiment comprises an ionizing zone 160, similar to that of the embodiment of Fig. 6, and a plurality of spray-nozzles 162 and 164 axially spaced in a gas-conduit 166. Each of the spray-nozzles 162 and 164 has associated therewith a field-establishing electrode 168 and 170, respectively, each in the form of a metallic loop.

Improved gas-cleaning efficiencies can also be obtained with improved spray-forming means capable of discharging the spray-liquid in greater quantities and in finer drops. The gas-cleaning efficiency can also be raised by decreasing the gas-flow velocity through the gas-cleaning apparatus.

Since the gas-conduits of the various embodiments are at ground potential, they attract negatively charged spray-drops, separating them from the gas-stream; and in the embodiment of Fig. 7 a small trough 172 is arranged along the sides of the gas-conduit for receiving water collected by the portion of conduit 166 in the precipitating zone.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is :—

1. The method of removing dust-particles from a flowing gas or air, characterised by electrically charging the dust-particles by passing the gas stream through an ionizing electrostatic field of predetermined polarity established between spaced positive and negative electrodes, and then through a spray of liquid passed through another electrostatic field of opposite polarity separately established by a charged electrode which charges the spray by induction with a polarity opposite from that of the dust particles, whereby the liquid drops and charged dust-particles are caused to attract each other.

2. The method, as claimed in claim 1, characterised by the use of water in the liquid-spray to which the charged dust-particles adhere.

3. The method, as claimed in claim 1 or 2, characterised by the step of neutralising to some extent the space-charge of the combined dust-laden stream of gas and liquid-spray.

4. The method, as claimed in claim 1, 2 or 3, characterised by the step of separating the dust-laden liquid from the cleaned gas.

5. Apparatus for carrying out the method of removing dust-particles from a flowing gas or air, as claimed in any of the preceding claims, comprising a gas conduit having an ionizing zone therein for ionizing the said dust-particles in the gas stream, characterised by a dust-removing means arranged to act upon the gas stream coming from the ionizing zone, said dust-removing means comprising at least one liquid-spray device and separate field-establishing electrode-means co-operating with the spray device for electrically charging the liquid-drops of the spray.

6. Apparatus, as claimed in claim 5, characterized in that the spray-device is electrically conductive and of a polarity opposite to the polarity of the ionizing means.

7. Apparatus, as claimed in claim 5 or 6, characterized in that the liquid-spray discharged from the liquid-spray device flows in the same direction as the gas-stream and spreads across the gas conduit.

8. Apparatus, as claimed in claim 5, 6 or 7, characterized in that the electrode-means cooperating with the spray-device has a charge of the same polarity as the polarity of ionization of the dust-particles.

9. Apparatus, as claimed in any of the claims 6 to 8, characterized in that the field-establishing electrode means cooperating with the spray-device is electrically insulated from said spray-device.

10. Apparatus, as claimed in any of the claims 5—9, characterized by space-charge controlling means disposed adjacent to or in the spray-treated region of the gas-stream for at least partially neutralizing the space-charge therein.

11. Apparatus, as claimed in claim 10, characterized in that the space-charge-controlling means comprises a plurality of plate-electrodes of some extent in the spray-treated region.

12. Apparatus, as claimed in any of the claims 5—11, characterized in that the electrode-means cooperating with the spray-device comprises at least one loop insulatedly spaced from and about said device.

13. Apparatus as claimed in any of the claims 5—12 inclusive characterised in that the liquid supply pipe is grounded.

14. Apparatus, as claimed in any of the claims 5—13, characterised in that the liquid-spray device comprises a pipe having a plurality of spaced spray-nozzles, and that the electrode-means co-operating with, and insulated from, said spray-device, comprises a plurality of spaced-loop electrodes, adjacent ones of said loop electrodes being in electrical contact.

15. The method of removing dust-particles from a flowing gas or air substantially as hereinbefore described.

16. The apparatus for removing dust-particles from a flowing gas or air constructed, arranged and adapted to operate substantially as hereinbefore described and shown in the accompanying drawings."

Dated this 20th day of April, 1942.

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Agent for the Applicants.

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Fig. 1.

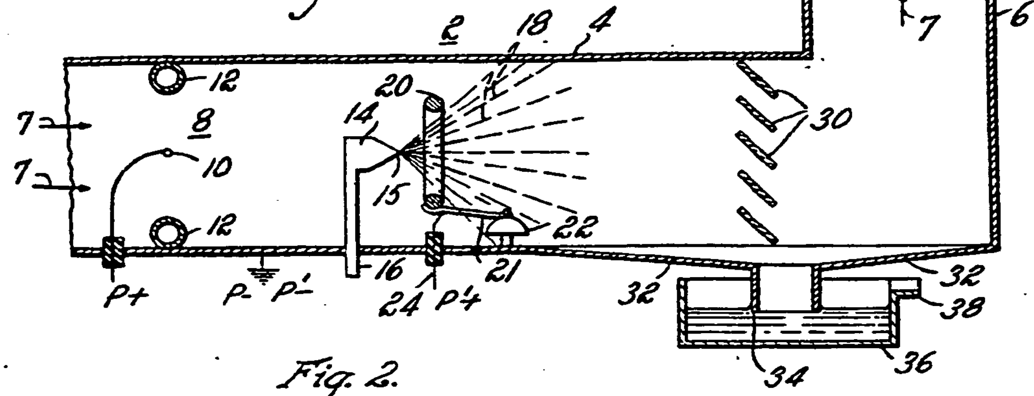


Fig. 2.

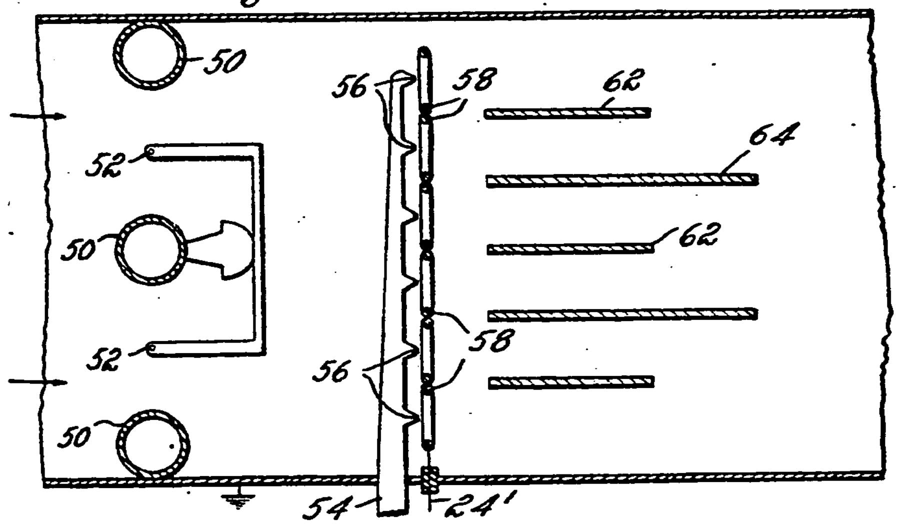
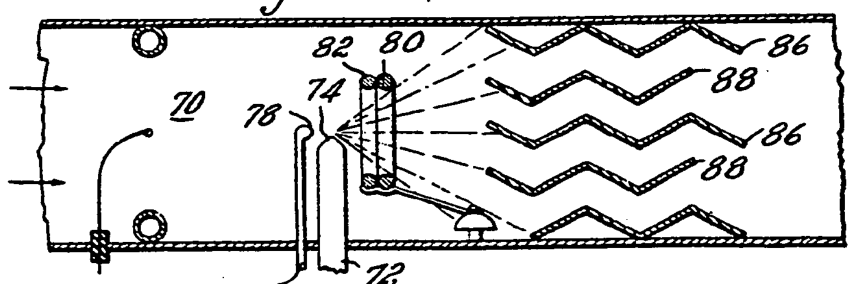


Fig. 3.



SHEET 1

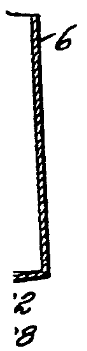


Fig. 4.

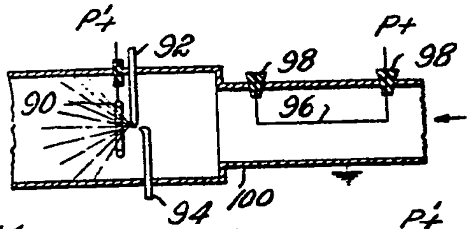


Fig. 5.

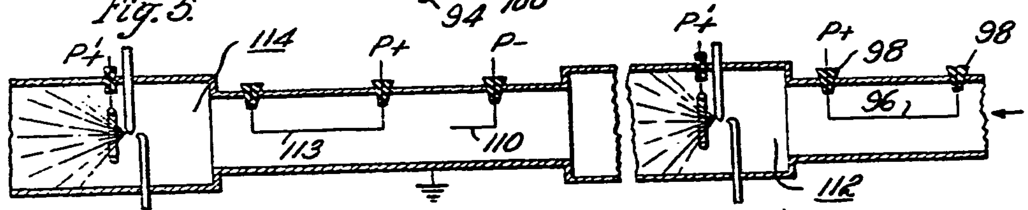


Fig. 6.

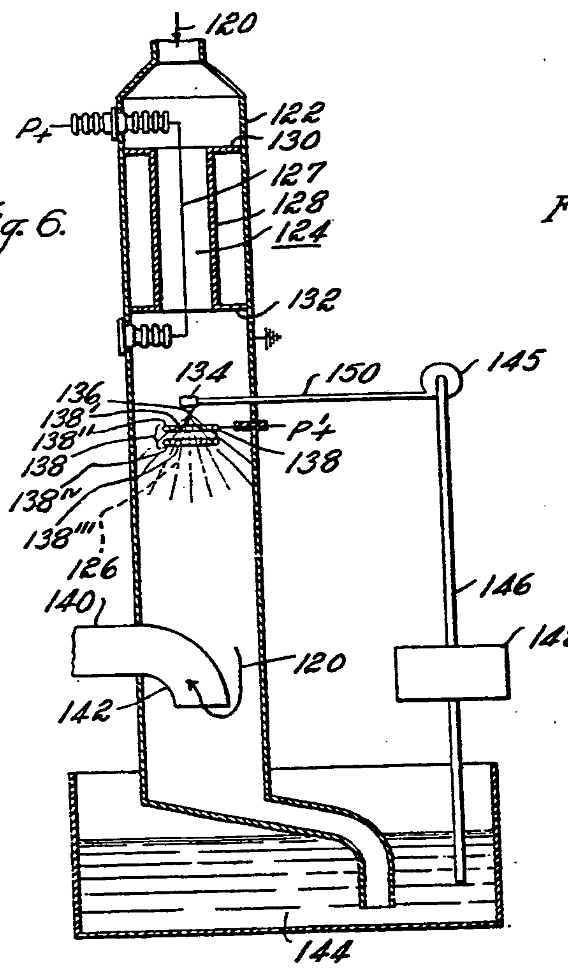
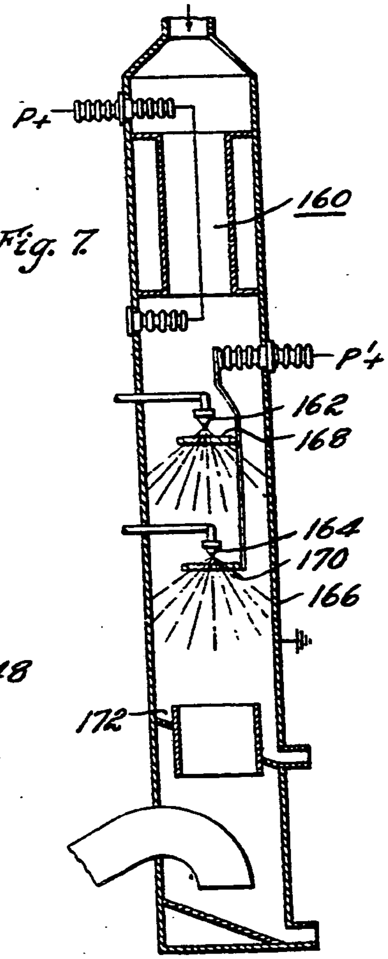


Fig. 7.



SHEET 1

Fig. 1.

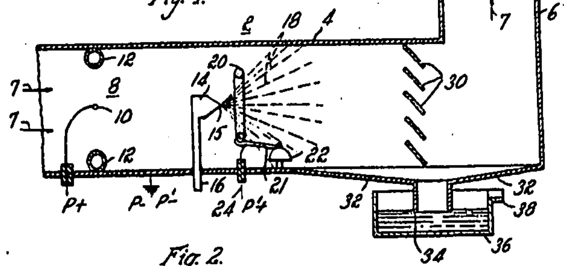


Fig. 2.

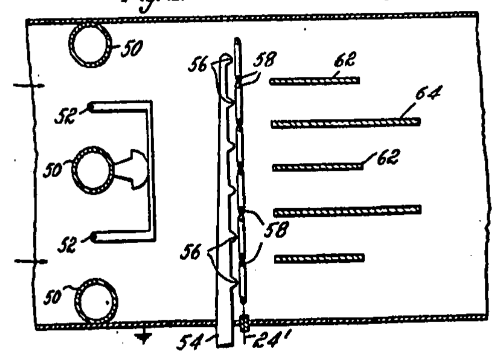
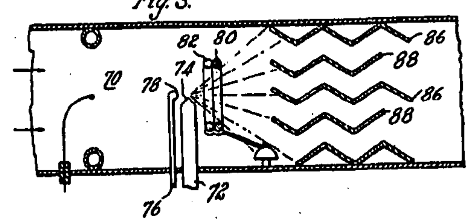


Fig. 3.



SHEET 2

Fig. 4.

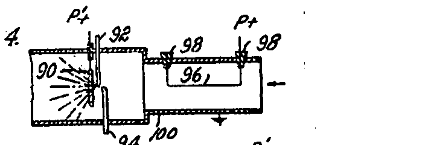


Fig. 5.

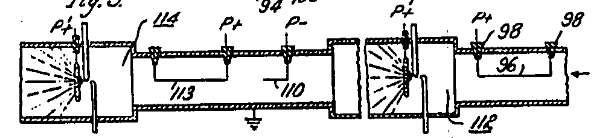


Fig. 6.

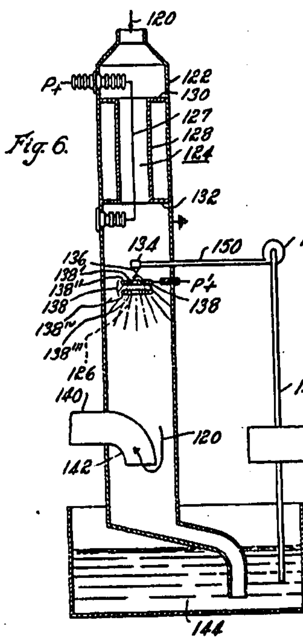
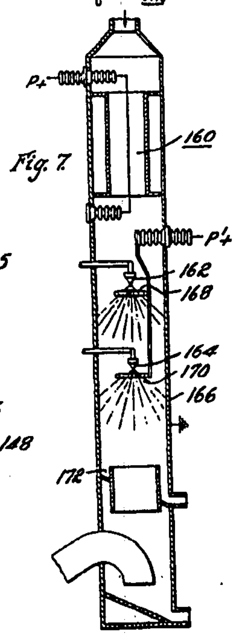


Fig. 7.



[This Drawing is a reproduction of the Original on a reduced scale.]

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